The current status of forest site classification in Ontario

by R.A. Sims[1] and P. Uhlig[2]

Abstract

Forest sites are diagnostic forest-landscape ecosystem units that resource managers must deal with during the planning and implementation stages of management. Forest sites are the basic building blocks for undertaking integrated resource management which weighs wildlife, recreation, environmental impact and various other concerns along with timber harvesting. Consequently, accurate and practical systems for classifying and mapping forest sites are becoming increasingly necessary to organize, communicate and use existing and new management knowledge and experience effectively.

Over the past four decades in Ontario, a number of studies and resource surveys have provided important background information on forest sites. Many have considered, to varying extents, the integrative roles of vegetation, soil-site, landform and general climate on forests and forest land. Generally, the emphasis has been on description and classification, with results generating a better understanding of how various forests in different areas develop, both qualitatively and quantitatively, in relation to soil-site or other features of the basic land resource. Some of these studies and surveys have been instrumental in advancing the definitions and understanding of forested ecosystems. Others have provided new information on site dynamics, interrelationships and functions, or have contributed to the science (and art) of site evaluation and classification.

This paper briefly summarizes the current status of forest site classification in Ontario. Over time, the role of forest site classification has evolved in response to new technologies and information, and to new emphases and values in resource management. In general, site classification research has become increasingly integrative and quantitative. Some of the important future challenges facing forest site classification in Ontario are briefly discussed.

Key words: ecological land classification, forest ecology, forest ecosystem classification, forest management interpretations, forest site classification, land use planning, Ontario.

Résumé

Les sites forestiers sont les unités diagnostiques de l'écosystème forestier ou paysager dont on doit tenir compte lors de la planification et de l'exécution d'un projet d'aménagement des ressources. Les sites forestiers servent de base à un aménagement intégré des ressources, tenant compte à la fois de la faune, des activités récréatives, des retombées environnementales, de plusieurs autres facteurs et de la récolte du bois. Il est par conséquent de plus en plus important de disposer de systèmes de classification et de cartographie des sites forestiers qui soient pratiques et précis afin d'augmenter et de mieux organiser, communiquer et utiliser notre connaissance et notre expérience en matière d'aménagement.

Durant les quarante dernières années, un certain nombre d'études et d'inventaires des ressources ont fourni des renseignements généraux importants sur les sites forestiers. Ils ont souvent intégré, à divers degrés, les rôles joués par la végétation, le sol et le site, les formes de relief et le climat sur les forêts et le territoire forestier. En général, on mettait l'accent sur la description et la classification, ce qui permet de mieux comprendre comment des forêts se développent, qualitativement et quantitativement, dans différentes régions, suivant les caractéristiques du sol ou du site, et d'autres éléments propres au terrain. Plusieurs de ces études et inventaires ont servi à mieux définir et à mieux comprendre les écosystèmes forestiers. D'autres ont fourni des renseignements nouveaux sur la dynamique, les corrélations et les fonctions des sites, ou bien ils ont permis de faire progresser la science (et l'art) de l'évaluation et de la classification des sites.

Cet article donne un bref aperçu de la classification des sites forestiers en Ontario à l'heure actuelle. Avec le temps, la classification des sites forestiers a vu son rôle évoluer pour répondre aux nouvelles technologies et connaissances ainsi qu'à un changement de priorités et de valeurs dans le domaine de l'aménagement des ressources. De façon générale, la recherche en matière de classification des sites va de plus en plus vers l'intégration et le quantitatif. L'article aborde certains des défis importants auxquels l'Ontario devra faire face en matière de classification des sites forestiers.

Mots clés : classification de l'écosystème forestier, classification des sites forestiers, classification écologique du territoire, écologie forestière, interprétations de l'aménagement forestier, Ontario, planification de l'utilisation des terres.

Introduction

Forest sites can be viewed as basic building blocks for undertaking integrated resource management, a process which weighs wildlife, recreation, environmental impact and various other concerns along with timber harvesting. They are diagnostic stand-level forest-landscape ecosystem units that resource managers must recognize and deal with appropriately during the planning and implementation stages of management. Consequently, accurate, consistent and practical systems for classifying and mapping forest sites are essential so that existing and new scientific knowledge and management experience can be organized, communicated and applied effectively. Moreover, a clearer knowledge of forest sites at the stand level provides an important basis for a better understanding of the processes and ecosystem relationships that exist and interact at broader landscape levels.

A variety of studies and resource surveys have provided information on forest sites in Ontario. Many have considered, to varying extents, the integrative roles of vegetation, soils, landform and general climate on forests and forest land. Some have given direction to the landscape-level interpretation of

[1]Forestry Canada — Ontario Region, Great Lakes Forestry Centre, P.O. Box 490, Sault Ste Marie, Ontario, Canada P6A 5M7.
[2]Applied Science and Technology Section, Forest Research Institute of Ontario, Ontario Ministry of Natural Resources, P.O. Box 1000, Sault Ste. Marie, Ontario, Canada P6A 5N5.

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land patterns, and to the use of mapping to address problems of multiple land-use planning at a variety of scales. Others have focused on the stand level, emphasizing site description and classification. Some of these stand-level studies have resulted in a much clearer understanding of the ecological dynamics of various forest sites. Collectively, these landscape-level and stand-level investigations have generated a better understanding of how various forests in different areas develop, both qualitatively and quantitatively, in terms of soil, landform, climate and other land resource features and values. These studies and resource surveys have been instrumental in refining the science (and art) of site evaluation and classification, within and outside of Ontario.

This paper summarizes progress in forest site classification research over the past 40 years, and briefly describes the current status of forest site classification in Ontario. Over time, the role of forest site classification has been modified in response to new technologies and information, as well as to changing roles, responsibilities and emphases in resource management. Approaches to forest site classification in Ontario have evolved continually in recent years as our needs, perspectives and social values have shifted, and as our experience and scientific understanding have increased. In general, forest site classification in Ontario has become increasingly comprehensive, integrative and quantitative.

Landscape-level Studies

Originally, forest site research in Ontario was undertaken to meet a need for accurate, descriptive resource maps. There was a strong interest in developing techniques and methodologies that could be employed to evaluate resource values critically, so that the most appropriate land-use activities could be matched with individual land units. This early form of ecologically oriented land survey was based on a philosophy of multiple land-use which ranked forestry objectively as a land use in relation to other potential uses such as recreation, wildlife habitat, or agriculture. Such an approach has considerable merit, and is consistent with current emphases on integrated resource management and sustainable forest management.

G. Angus Hills (1902-1979) was a pioneer of the ecological approach to understanding and describing forest sites in Ontario (Jacobs 1979). Hills initiated forest site-related research in Ontario during the 1940s, drawing on his extensive practical experience in pedology and soil mapping, as well as a thorough understanding of contemporary European approaches to landform description, plant sociology and forest mensuration. During the 1950s and 1960s, Hills and his colleagues, working at the provincial Department of Lands and Forests, developed what was referred to as the "Ontario Site Classification System" (Hills 1952, 1953, 1954, 1958, 1960, 1961; Hills and Pierpoint 1960; Hills *et al.* 1970). This hierarchical classification was designed to stress physiographic characteristics of sites and was organized as a multi-level framework for forest management information (Figure 1).

At the broadest level, Site Regions were based on the observation and interpretation of vegetation-landform coincidences which also expressed major zonations of the macroclimate continuum (Figure 2a,b; Hills 1960). Hills (1953) described Site Regions as broad geographical zones within which specific plant successions occur on specific landform

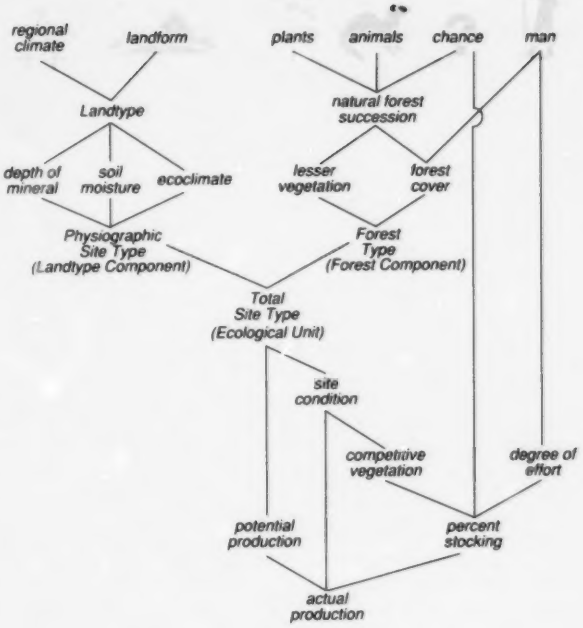

Figure 1. Some of the interrelated components described by Hills' Ontario Forest Site Classification; this chart shows how the system stresses physiographic characteristics and ecological relationships which influence forest production (after Hills 1961).

positions. The detailed taxonomic level of the typical forest stand (the so-called "Total Site Type") consisted of two components: the "Physiographic Site Type" and the "Forest Type", both of which were characterized by specific physical and vegetational features (Hills 1958; Hills and Pierpoint 1960; Hills *et al.* 1970). Physiographic Site Types were defined by narrow ranges in the depths of geological materials within the rooting zone, the soil moisture regime and the local climate. Forest Types were defined as a specific combination of overstory tree species and understory vegetation species occurring repeatedly on similar physiographic conditions at the same stage of forest succession within a given Site Region (Hills and Pierpoint 1960). "Landtypes" were also featured prominently in Hills' classification. Landtypes, defined as landforms within a given Site Region that exhibited narrow ranges of soil texture and mineral composition within the normal rooting depth of trees, were often used as a primary mapping unit (Hills and Pierpoint 1960; Figure 1).

At all levels, Hills' classification dealt with the recognition of mapping units at appropriate scales. A number of reference area survey programs using the system were conducted during the late 1950s and early 1960s. Individual studies were undertaken to demonstrate the applicability of Hills' approach to multiple-use planning, with mapping units and subsequent interpretations based on the inherent biological capability of the landbase. Investigations were performed on areas of various sizes ranging from as small as approximately 50 km^2 (Lynn and Zoltai 1965) to entire administrative Districts (Hills 1963; Keenan and Hills 1964) and Regions (Zoltai 1965, 1974) which cover 10,000 km^2 or

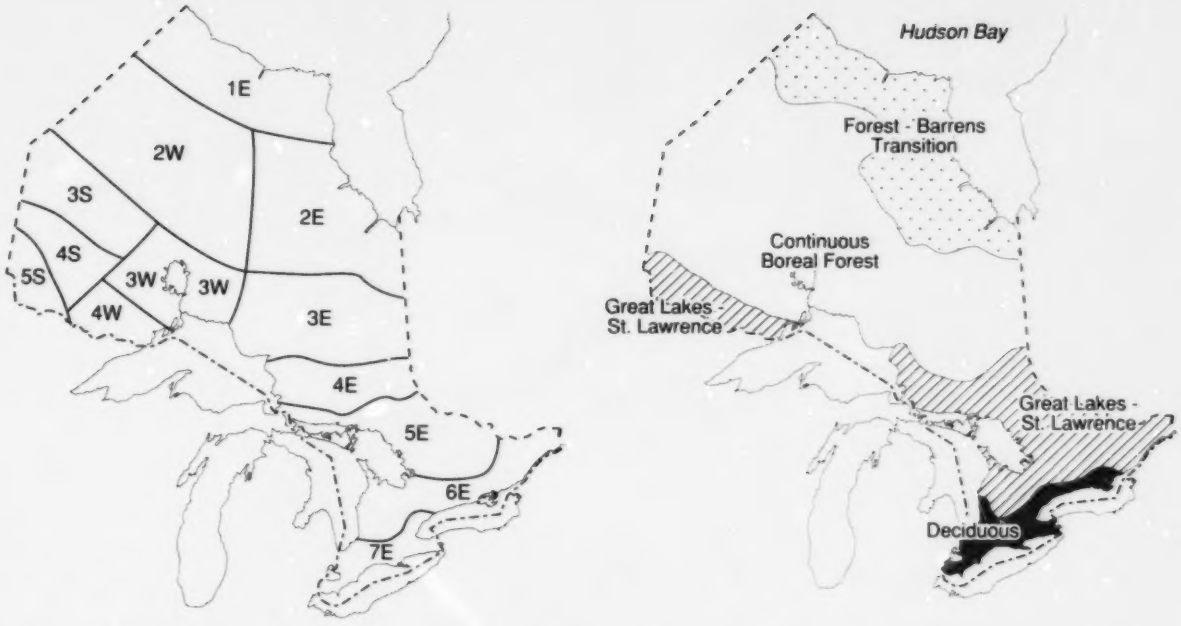

Figure 2. Maps of Ontario showing regional breakdowns: (left) Physiographic Site Regions (Hills 1953, 1960), (right) Forest Regions (Rowe 1972).

more. A primary emphasis in these reference area studies was the characterization of landtypes and their configuration through an integrative treatment of physiography, soils, climate and vegetation (Burger 1972a). In most of these reference area studies, greater importance was placed on describing physiography and soils rather than vegetation, although vegetation clearly had its place in the overall classification framework.

In many instances, the development of resource maps was augmented by a systematic analysis and ranking of land capability or potential for forestry, agriculture and appropriate levels of economic development (Hills 1942; Hills and Pierpoint 1960; Pierpoint 1962; Pierpoint and Hills 1963). This exercise required careful definition and use of detailed and innovative mapping procedures, and the derivation of relatively complex capability or suitability rankings (Hills 1960; Pierpoint and Hills 1963). The comprehensive land-use plans and interpretive maps developed for the Glackmeyer Development Area (Hills *et al.* 1960) and Tweed Township (Keenan and Hills 1964) are excellent examples of multiple-use valuations for land development planning using physiographic site information in combination with other resource data.

The mapping techniques developed by Hills and his colleagues were very comprehensive and provided a major influence on the later development of both the Canada Land Inventory (Anonymous 1965; McCormack 1966, 1970) and the Ontario Land Inventory (Anonymous 1977), two major land capability evaluation programs that mapped extensive areas of the province at scales of 1:250,000 and smaller. Mapping and site classification approaches developed by Hills (1952, 1960, 1961) were also in part adapted to an extensive set of land classification surveys conducted mainly in northern Canada during the late 1960s and 1970s. Referred to as Biophysical Land Classification (Lacate 1969) or Ecological Land Classification (Wiken *et al.* 1981; Wickware and Rubec 1989), these programs were undertaken mainly to provide broad-scale multiple-resource inventories of northern terrain or broad-area treatments at a regional or provincial level.

Forest stand classification based on height-age relationships has been used for many years in Ontario for yield forecasting. The "Site Class", based on tree height and age (Plonski 1974), is estimated for every mapped forest stand in the provincial Forest Resource Inventory (FRI) (Osborn 1989). Site Class conveys valuable information for forest harvest planning, but the usefulness of this type of height-age classification, by itself, is limited for many other purposes (Burger 1976; Jones 1984). Currently, there are limited numbers of other resource survey databases in Ontario and each provides only part of the information really needed for silviculture or integrated resource management purposes (Table 1). Pierpoint and Uhlig (1985) provide a complete listing and summary of the available resource surveys for the province.

Recently, Prime Site classification has been tested in Ontario as a tool for assisting regional forest management. Prime Site classification attempts to integrate, by means of Geographic Information System (GIS) modeling approaches, more stable physical site parameters and current wood volumes with other important but changeable technological and socio-economic criteria such as location in relation to transportation corridors and market conditions. Background work to delineate the physical map units as a basis for this work has been initiated in various parts of northern Ontario (Greenwood 1987; Towill and Sims 1989; Burger and Pierpoint 1990). Forest planning decision support systems and timber supply models are currently being developed for pilot

Table 1. An estimate of the abilities of existing resource inventories in Ontario to meet some of the various informational requirements for integrated resource management (O=not useful, X=useful, XX=very useful).

	FRI[1]	FEC	Agricultural Soil Survey	OLI	SO/NOEGTS
Planning horizon					
Short-med. term (1-5 yr)	XX	XX	X	X	X
Long-term (5-20 yr)	XX	XX	XX	XX	XX
Normal scale/resolution	1:20 000	Ground-based	1:10 000 (variable)	1:250 000	1:100 000
Extent of coverage in Ontario	Widespread	Local surveys only	Mostly scattered over small areas	Widespread	Widespread
Species composition	XX	XX	O	O	O
Working group	XX	X	O	O	O
Stand density and spacing	XX	X	O	O	O
Present productivty	XX	XX	O	O	O
Potential site quality	O	XX	XX	X	X
Product type/product amount	X	X	O	O	O
Non-commercial forest types	X	X	X	O	O
Depth of mineral soil	O	XX	XX	X	X
Depth and type of organic matter	O	X	XX	X	X
Soil moisture regime	O	XX	XX	XX	X
Soil texture	O	XX	XX	XX	XX
Macro/microtopography	O	X	XX	X	X
Surfical geology/landforms	O	X	X	X	XX
Wildlife browse prediction	O	XX	X	O	O
Fisheries concerns	X	X	XX	X	XX
Competition prediction	O	XX	X	O	O
Windfirmness	X	X	X	O	O

[1]FRI = provincial Forest Resource Inventory (Osborn 1989), FEC = Forest Ecosystem Classification, OLI = Ontario Land Inventory (Anonymous 1977), SO/NOEGTS = Southern Ontario-Northern Ontario Engineering and Terrain Survey maps (e.g. Mollard and Mollard 1981).

mapping areas, for example as part of the Plonski Forest study (Bulger and Hunt 1991), and will provide the computer-assisted capability to test Prime Site concepts rigorously.

Stand-Level Studies

Prior to 1970, detailed ecological data sets were not gathered for the purpose of comprehensive analysis, and most field data collected at the stand level was acquired either as demonstration material or to assist photo-interpretation exercises for land inventories such as the Ontario Land Inventory (Anonymous 1977). In addition, statistical methods and computer capabilities for handling, processing and evaluating such large datasets were not yet sufficiently developed and available.

Pre-1970 stand-level investigations by Hills and his colleagues contributed significantly to basic concepts of forest site description (Burger 1972b, 1977; Pierpoint 1981). Their investigations provided some important initial documentation and description of stand-level conditions (Hills 1950, 1952, 1954; Pierpoint 1962, 1981). In a land-use study of the Glackmeyer Development area in the Northern Clay Belt, Hills and his colleagues (1960) provided a remarkably thorough treatment of forest succession patterns as they relate to the commonly occurring physiographic sites in the area. Each vegetation description included summaries of dominant soil moisture regime, depth to bedrock, landform and humus type, as well as comments on possible succession patterns after disturbance (Hills *et al.* 1960). Applying Hills' classification approach to a broad study area in northwestern (NW) Ontario, Zoltai (1965, 1974) identified 24 landtypes defined primarily on the basis of geological material, soil texture, soil depth and stoniness. Zoltai (1965) also described the common overstory associations which occur across each of these landtypes. Studies such as these have prompted scientists and foresters to focus on important site-related criteria controlling forest growth and development at the stand level.

There are a number of other important early contributors to stand-level site classification in Ontario. Working in the Northern Clay Belt of northeastern Ontario, MacLean and Bedell (1955) conducted a growth and yield survey of forest stands emphasizing the influence of topographic location and soil wetness on forest productivity. They recognized several groupings of upland and lowland forest types mainly on the basis of soil characteristics such as "wet swamp", "very wet swamp" and "shallow peatlands". Earlier, for a broad area centered around Lake Nipigon, 13 merchantable and three unmerchantable site types were also recognized on the basis of similar topographic and soil wetness criteria (Bedell and MacLean 1952). Stratifying these units mainly on the basis of broad soil texture classes, Bedell and MacLean correlated these site types with selected mensurational measurements. For the Abitibi Woodlands Laboratory near Raith, Ontario, Losee (1955) developed a preliminary site classification system that identified nine different understory vegetation communities. They were grouped into categories he thought could be correlated with low, intermediate and high soil fertility levels. Ahti and Hepburn (1967) undertook an aerial reconnaissance and ground survey over a broad area of the Precambrian Shield north of Lake Superior in an attempt to assess the quality of woodland caribou habitat. They presented a general vegetational community classification for lichen-dominated upland stands as well as a wetland classification based on general physiognomy and dominant vegetation. For portions of the Hudson Bay Lowland of northern Ontario, Hustich (1957) and Sjors (1961, 1963) provided comprehensive descriptions of upland and lowland vegetational communities in relation to site factors such as soil texture and groundwater chemistry. Other

researchers such as Maycock (1960, 1963) examined the vegetational relationships of upland forest stands in southern and central Ontario as well.

In the period after 1970, there was a considerable amount of work conducted on stand-level forest ecology; as well, new information on function and dynamics was obtained. In general, studies were more quantitative, allowing ecological relationships to be examined more critically (Carleton and Maycock 1978; Carleton 1980, 1985; Kenkel 1986; Carmean 1987). Vegetational studies on Ontario wetlands and peatlands were conducted as a basis for developing site classifications (Jeglum *et al.* 1974; Jeglum and Boissonneau 1977; Sims *et al.* 1982; Vitt and Bayley 1984; Kenkel 1987; Cowell *et al.* 1991). Jeglum (1985) summarizes important developments in wetland site classification in Ontario.

Many of these landscape-level and stand-level research studies and resource surveys provided excellent baseline information on the forest ecosystems of Ontario. Hills and his colleagues, and ensuing studies by others, also provided a great deal of philosophical and methodological background on forest site and forest land classification. In the late 1970s, against this backdrop, and amidst evolving forest site classification activities in other parts of North America, the first of what were to be a series of Forest Ecosystem Classification (FEC) programs was begun in the Northern Clay Belt (Jones *et al.* 1983; Jones 1984).

Figure 3. Map of Ontario showing the extent of geographic coverage by Forest Ecosystem Classification systems; *completed* (diagonal hatching) and *in progress* (dot pattern).

Development of Forest Ecosystem Classifications in Ontario

General

FEC systems have been completed or are currently in development for a broad geographic zone across north-central Ontario (Figure 3, Table 2), covering most of Rowe's (1972) Boreal and Great Lakes-St. Lawrence Forest Regions. Small area studies using an FEC approach have also been completed (Wickware and Cowell 1985).

The FEC systems in Ontario are designed to permit the accurate, consistent and practical description of forest ecosystems so that existing and new management knowledge can be organized, communicated and used more effectively. FEC units are flexible and at least partly hierarchical; some demonstration studies have been undertaken to show that units can be mapped at various scales as well as integrated with other data bases to augment the background information for an area for forest planning and decision making.

The most recent FEC programs (Jones *et al.* 1983; Merchant *et al.* 1989; Sims *et al.* 1989) have been enthusiastically received. Concise and accessible formats coupled with a major effort in training and transfer has meant that FEC terminology and ecosystem thinking is becoming part of the resource management culture of Ontario. The user group now includes the public, policy makers, researchers and planners for a variety of resource fields. Applications range from wildlife habitat evaluations, environmental assessment and forest growth and yield interpretations, to the use of FEC units as a basis for keeping landbase records and monitoring long-term effects.

Rationale and Approach

A primary consideration in the development of FECs is that they are purposive. It should be noted that the FEC systems in Ontario, without exception, were first constructed for a specific and predefined range of uses. These included the organization of silvicultural practice and knowledge and the orientation of practical forest management information within a framework that recognized on-the-ground characteristics of understory vegetation, soils, landform, general climatic regime and regional physiography (Table 2).

FEC systems are primarily stand-level planning tools. They are designed to help foresters and other resource users obtain specific descriptive information about local forest stand, vegetation, soil and site conditions, which in turn can help develop management strategies and alternatives. Used and applied in a somewhat different way, the regional FEC systems are also effective mechanisms for tying in other scales of forestry data and other levels of planning information.

In the existing Ontario FEC systems, Vegetation and Soil Types are basic units. Both are determined through a "key-out system" that can be applied in the field quickly. For certain broader-level management purposes, FEC units come together as Operational Groups (OGs) (Jones *et al.* 1983), Treatment Units (TUs) (Sims *et al.* 1989) or Site Types (STs) (Merchant *et al.* 1989).

FEC Programs

FEC data collection standards were developed in 1978 during the initial phases of the Clay Belt FEC program (Jeglum *et al.* 1983; Jones *et al.* 1983). Field work was conducted during successive summers. Computerized FEC databases were constructed. For each area investigated to date they include detailed soil, site and vegetation information from mature or harvestable forest stands. Currently, a centralized computer inventory contains data on approxi-

Table 2. An overview of completed and ongoing Forest Ecosystem Classification programs in Ontario (NER FEC = Northeast Region FEC, CR FEC = Central Region FEC, IRM = integrated resource management).

	Clay Belt (Jones *et al.* 1983)	NER FEC	NW Ontario (Sims *et al.* 1989)	Algonquin[1] (Merchant *et al.* 1989)	CR FEC
Parameters					
Completion date	1983	ongoing	1989	1989	ongoing
Extent of coverage	50 400 km^2	—	184,000 km^2	35,300 km	—
Emphases	silviculture	IRM	silviculture & IRM	productivity of Pw and Pr	IRM
Main FEC units	14 Soil and 23 Vegetation Types, Operational Groups	ongoing	22 Soil and 38 Vegetation Types, Treatment Units	10 Soil and 14 Vegetation Types, Site Types	ongoing
Number of FEC plots	250 plots	—	2170 plots	201 plots	—
Management interpretations for					
Harvesting/silviculture	yes	—	yes	yes	—
Stand/site productivity	yes	—	yes	yes	—
Wildlife & other resources	yes	—	yes	no	—
Pilot mapping studies	yes	—	yes	no	—

[1]The Algonquin FEC deals only with white pine (Pw)- and red pine (Pr)-dominated forest ecosystems; when completed, the CR FEC will describe other forest ecosystems.

mately 2,800 FEC plots throughout the province (McLean and Uhlig 1990).

Information on the use of the various FEC systems has been transferred to operational staff through the publication of reports, maps and field guides, together with an intensive, ongoing training program. Three- and four-day FEC courses have been conducted throughout Ontario over the past 8 years (e.g., see Sims 1990) in basic forest soils description, identification of forest vegetation, field applications and interpretations, and mapping of soil-landform relationships.

Application of FEC Systems

The FEC systems in Ontario provide a set of regional frameworks for site description. Vegetation and Soil Types determined from field keys are described in sets of accompanying fact sheets. Once a forest site has been classified, a variety of short- and medium-term forest management interpretations may be considered and applied. The systems are applicable at a variety of levels and intensities, and are valuable to different users and for applications that involve various forest management objectives. For example, as a stand-level tool, FEC systems have been applied successfully as part of an operational cruise or pre-harvest assessment procedure (Stanclik 1986; Towill *et al.* 1988; Campbell 1990).

Through a keying process, forest stands can be allocated to specific FEC Vegetation and Soil Types in the field. Once allocated by means of these keys, stands are compared to corresponding factsheet descriptions of Vegetation and Soil Types in the FEC field guides (Jones *et al.* 1983; Sims *et al.* 1989; Merchant *et al.* 1989). While the allocation process varies somewhat among the completed systems, in general it follows two steps:

- The forest stand is allocated to a Vegetation Type. The user applies a field key that incorporates overstory trees and diagnostic understory plants.
- The soil profile underlying the stand is allocated to a Soil Type. The user applies a field key which asks for a few critical soil parameters (e.g., soil depth, parent material texture, soil moisture regime) determined through an examination of soil material from either a soil pit or an auger hole.

Computer-assisted ordinations (Hill 1979; Gauch 1982) provided a means to summarize FEC vegetational cover information succinctly. Ordinations have been used widely to study vegetational relationships within boreal forest ecosystems (Carleton 1980, 1985; Zelazny *et al.* 1989; Cowell *et al.* 1991). Ontario FEC ordinations (e.g. see Figure 4a,b) were based on percentage cover and relative abundance information for a large number of vegetation species recorded in 10 × 10 m sample plots. The FEC ordinations portray Vegetation Types within soil moisture-nutrient two-dimensional graphs, much in the way that the Alberta and British Columbia biogeoclimatic systems organize ecosystem units within edatopic grids (Corns and Annas 1986; Green 1990). Information about other soil, site or vegetation parameters is readily overlaid on FEC ordinations as a means of highlighting relationships (Wearn *et al.* 1982; Jeglum *et al.* 1983; Jones 1984; Racey *et al.* 1989a; Baldwin and Sims 1989).

Operational Groups and Treatment Units

Operational Groups (OGs), Treatment Units (TUs) and Site Types (STs) are management-oriented aggregations of FEC Soil and Vegetation Types that possess similar species composition, productivity, and macroclimatic or ecological properties (Jones *et al.* 1983; Racey *et al.* 1989a; Merchant *et al.* 1989). OGs, TUs and STs are easily determined in the field and usually represent broad landscape units that should respond similarly to a given regime of silvicultural treatments. They provide aggregations of FEC units that can, in some situations, be used to develop interpretations for forest management (Figure 4a,b, 5). Similar OG or TU units are used to help describe forest management options in New Brunswick (Zelazny *et al.* 1989), Alberta (Corns and Annas 1986) and British Columbia (Klinka *et al.* 1984).

OGs, TUs and STs are less precise in describing soil-site and vegetational characteristics than are FEC Vegetation and Soil Types, but it is often possible to re-divide them into

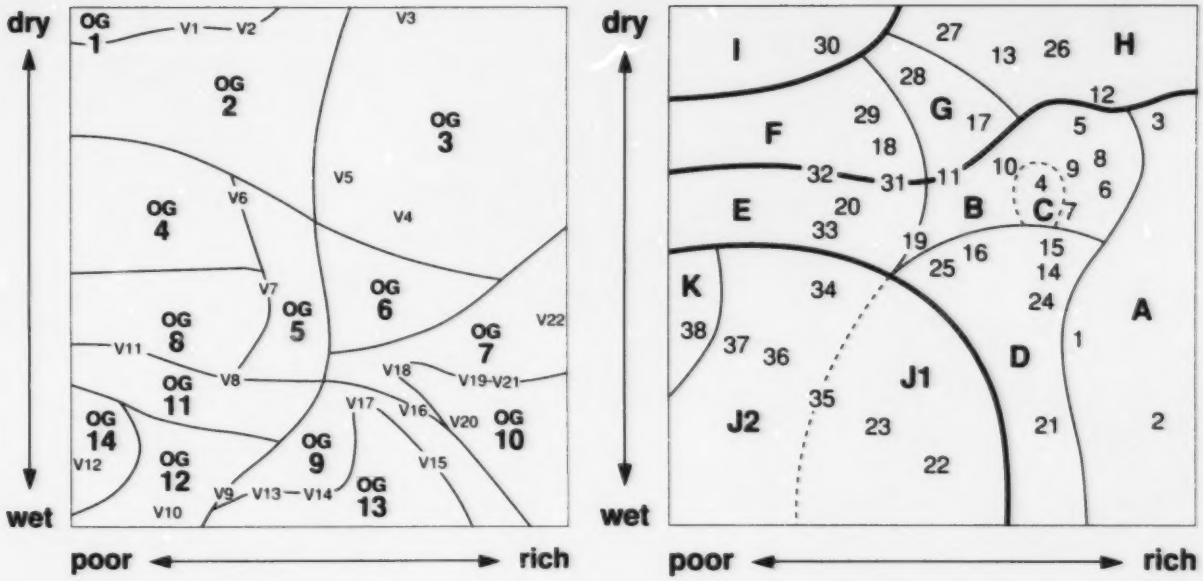

Figure 4. (left) Clay Belt FEC vegetational ordination of Vegetation Types overlain with Operational Groups and showing broad gradients of nutrients (x-axis) and moisture (y-axis) (Jones *et al.* 1983), (right) NW Ontario FEC vegetational ordination showing Vegetation Types overlaid by Treatment Units and with similar moisture/nutrient gradients (Sims *et al.* 1989).

component Vegetation and Soil Types. OGs, TUs and STs can also be delineated into Phases in which secondary features can influence certain specific responses to management activities. Phases serve to focus management options, and can be defined, for example, on the basis of soil moisture regime groupings (cf. Racey *et al.* 1989a) and shrub-richness or soil-depth classes.

FEC as a Framework for Forest Management Interpretations

A wide variety of forest management interpretations have been integrated with site classification systems (e.g., Corns and Annas 1986; Kotar *et al.* 1988; Zelazny *et al.* 1989; Green 1989). Similar approaches have been used to develop forest management interpretations for Ontario FEC systems (Tables 2 and 3; see also Jones *et al.* 1983; Jones 1984; Racey *et al.* 1989a; Merchant *et al.* 1989; Stocks *et al.* 1990). Five different examples of FEC-based forest management interpretations are outlined in the following sections.

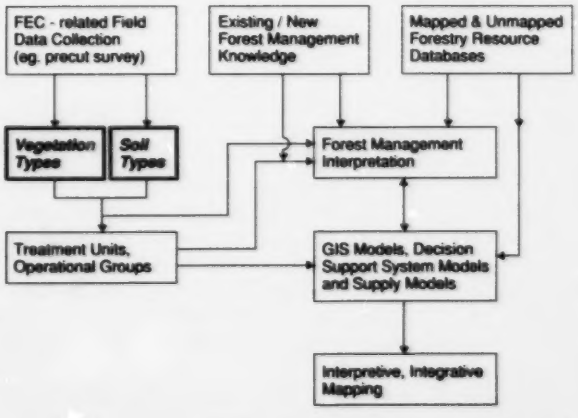
FEC - related Field Data Collection (eg. precut survey)
Existing / New Forest Management Knowledge
Mapped & Unmapped Forestry Resource Databases
Vegetation Types
Soil Types
Forest Management Interpretation
Treatment Units, Operational Groups
GIS Models, Decision Support System Models and Supply Models
Interpretive, Integrative Mapping

Figure 5. Organization of FEC Soil and Vegetation Types so that, with the input of management information and knowledge, management interpretations and other products may be developed iteratively.

Preparing Prescribed Burn Guidelines

Prescribed burning is used by foresters to achieve specific management objectives such as slash reduction, wildfire hazard reduction, disease control, site preparation for regeneration, wildlife habitat improvement or any combination of these or other objectives. Planning for prescribed burns should consider all relevant site factors, including expected fuel loading, substrate, soil moisture and physiography.

FEC units can be used to stratify sites for the calculation of the required fire intensities, and the determination of the vegetation and soil conditions to be considered in the planning of prescribed burns. Wearn *et al.* (1982) provide a Clay Belt FEC interpretation for prescribed burns in which the management objective is to prepare the site for hand planting. An ordination overlay (Figure 6) is used to assist the manager in determining the required intensity of burns. Accompanying sets of pre- and post-burn colour site photos (Wearn *et al.* 1982) are catalogued according to FEC Vegetation Type, and provide an additional aid for the forester, indicating results that might be expected on different sites given different sets of fire weather indices.

A similar ordination overlay is provided for the NW Ontario FEC by Racey *et al.* (1989a). Fuel loadings and wildfire potentials of Vegetation Types have also been estimated (Stocks *et al.* 1990).

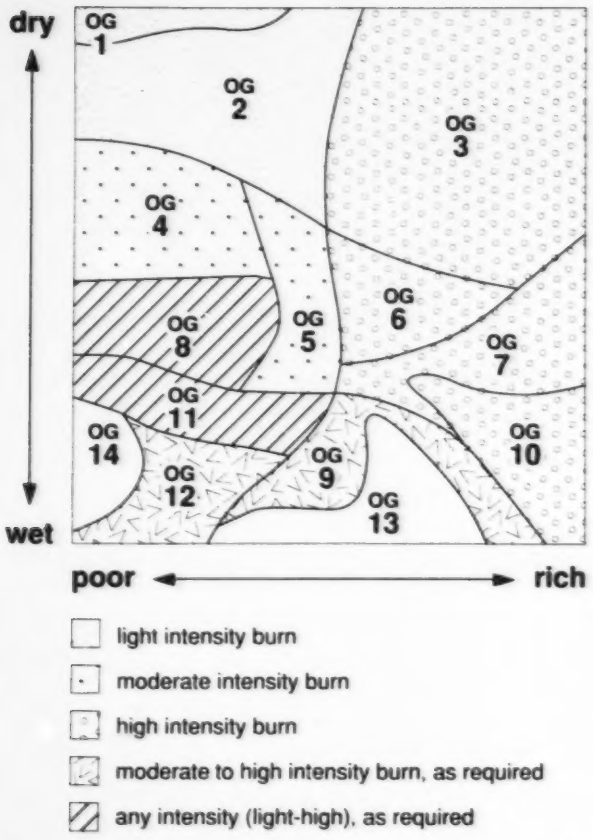

Figure 6. Clay Belt FEC ordination (as in Figure 4a) showing recommended intensities for prescribed burns as a site preparation technique prior to hand planting (after Wearn *et al.* 1982).

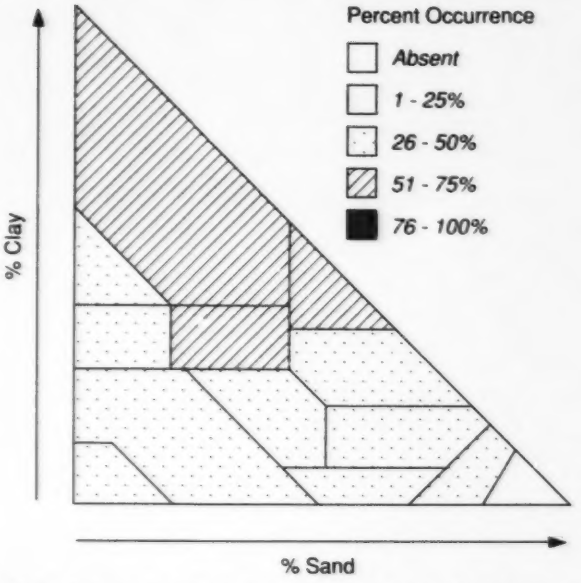

Figure 7. Frequency of occurrence of beaked hazel (*Corylus cornuta* Marsh.) according to soil texture classes, shown as an overlay on a soil texture triangle; based on field information summarized from the NW Ontario FEC program (Bell 1991).

Organizing Ecological Information on Competitive Species

When combined with keen field observational skills and experience, summarized autecological information on competitive species, presented within a site classification framework, can help foresters improve forest vegetation management practices significantly (Wagner and Zasada 1991). There are 23 common understory species identified as serious competitors with crop trees in NW Ontario. For each species, Bell (1991) reviews a variety of descriptive information such as associated NW Ontario FEC Vegetation and Soil Types, life cycles, reproduction, and soil-site characteristics conducive to growth (Figure 7). There are also summary comments for each species in terms of the forestry practices that stimulate or reduce growth or establishment, and the utilization of the species by wildlife. Information is summarized on current methods used for control or management of the species.

Summary information on the ecological range of other understory vegetation species is provided in a plant identification guide for the NW Ontario FEC (Baldwin and Sims 1989). This handbook provides identification aids and habitat information on 157 forest plant species, including common trees, shrubs, herbs, graminoids, ferns, mosses and lichens. The publication includes individual NW Ontario FEC ordination diagrams for each species and shows associated Vegetation Types and species distributions across interpreted moisture-nutrient gradients.

Estimating Soil-Associated Constraints on Forestry Operations

A variety of operational constraints can be related to soil texture, soil moisture, the presence of significant quantities of coarse fragments, and other soil parameters that may be associated with or derived from FEC Soil Types. For example, soils generally become less susceptible to erosion as clay or sand content increases, and more susceptible as silt content increases. A soil's surface condition (e.g., residual vegetation, surface texture, etc.) and the frequency, intensity and duration of rainfall can also influence a local area's susceptibility to soil erosion. In addition, susceptibility to erosion is often greatest where slopes exceed 10%; long, steep, uniform slopes are particularly vulnerable. Erosion generally decreases with increasing amounts of residual vegetation and slash left on a site, and increases with an increasing degree of disturbance to surface organic layers.

Such considerations are incorporated into a simple NW Ontario FEC interpretation that deals with the soil erosion hazard (Figure 8). The chart, intended to be used in the field as a "look-up table", provides low, moderate and high erosion-hazard ratings that are based on NW Ontario FEC Soil Types (Racey *et al.* 1989a). Its intent is to alert the forest planner to potential problems; moderate or high ratings should prompt consideration of measures to reduce potential soil erosion.

The Kapuskasing District of the Ontario Ministry of Natural Resources (OMNR) has produced a photo guide to harvesting and regeneration options using the Clay Belt FEC as a framework for site descriptions (Anonymous 1987). The photo guide provides pre- and post-harvest sets of color

Table 3. Selected examples of forest management interpretations based on the Northwestern Ontario Forest Ecosystem Classification.

Interpretation	Main FEC Units	References
Silviculture		
Determining the competition potential for selected understory species	Vegetation Types/ Soil Types	Bell (1991), Baldwin and Sims (1989)
Defining the autecological preferences of common tree species	Vegetation Types/ Soil Types	Sims et al. (1990), Bell (1991)
Predicting the productivity of jack pine stands	Soil Types	Leblanc and Towill (1989), Racey *et al.* (1989a)
Predicting the potential for advance growth following logging	Vegetation Types	Wickware *et al.* (1990), Walsh and Wickware (1991)
Wildlife habitat		
Predicting moose habitat preferences	Vegetation Types	Racey *et al.* (1989b), Jackson *et al.* (1991)
Predicting habitat selection by forest-nesting bird species	Vegetation Types	Racey *et al.* (1989a)
Predicting caribou habitat preferences	Vegetation Types	Morash and Racey (1990)
Landscape features		
Correlating surficial landform features with FEC Units	Soil Types	Sims *et al.* (1991)
Interpreting black and white air-photos for FEC units	Vegetation Types/ Soil Types	Wickware (1989)
Constructing common toposequence patterns for landform complexes	Vegetation Types/ Soil Types	Baldwin *et al.* (1990)

photos with information on soil characteristics, vegetation competition after harvesting and the extent of soil degradation that can occur if narrow-wheeled harvesting equipment is used on certain organic Soil Types. A videocassette recording also accompanies the report and photo sets (Anonymous 1987).

Soil conditions influencing erosion hazard

NWO FEC Soil Types*	Slope (%)	Erosion Hazard	Comments
S12F, S12S, S5B, S11		Low	
S2, S4, S5, S7B, S11, S5T, S5Z, S53, S54, S57, S5B	≤10 >10	Low High	Fluvial materials or extensive surface disturbance will increase hazard
S1, S3, S5, S6, S7, S8, S55 S5B	≤10 >10	Low Moderate	Morainal soil materials, variable particle sizes, coarse fragment content >35%, or thick surface organic layers may reduce the erosion hazard

* assumes a relatively close correlation between surface texture and C horizon texture

Figure 8. Prediction of potential erosion hazard (low, moderate, high) on the basis of Soil Types from the NW Ontario FEC system (Racey *et al.* 1989a).

Predicting the Productivity of White and Red Pine

A number of investigations have been undertaken to examine site productivity relationships of FEC units. The Algonquin Region FEC (Merchant *et al.* 1989) incorporates a methodology for estimation of white and red pine productivity. To apply the system, a given stand must meet several criteria: it must be natural pine-conifer only, have an estimated minimum of 60% white pine or red pine by basal area, be relatively fully stocked, have been undisturbed for the past 25 years, and be mature, usually at least 75 years of age. As in the other FEC systems (although sometimes the Soil Type in a given location may be inferred from the Vegetation Type), it is more accurate to determine the Soil Type directly either by digging a soil pit or augering a hole.

The Algonquin FEC system uses a combination of Vegetation Types and commonly associated Soil Types to characterize Site Types (STs), which are in turn related to classes of site index at 75 years and mean annual increment for each of the two pine species (Merchant *et al.* 1989). STs are defined as classes of similar forest ecosystems on the basis of soil and vegetation features that can affect forest productivity and management. Additional productivity information is summarized by STs in Taylor and Jones (1989). The Site Type Information Table (Figure 9) associated with each Vegetation Type fact sheet also provides common soil-site conditions, a "quality warning" which gives some indication of potentially decreased stem quality due to rot, and a rating of potential competition (low, moderate, high, very high) after harvest (Merchant *et al.* 1989). Other studies that have specifically examined productivity relationships with FEC Vegetation and Soil Types include Munson and Timmer (1989a,b), LeBlanc and Towill (1989), Whynot and Penner (1990), Buse and LeBlanc (1990) and Li (1991).

Describing the Habitat of White-tailed Deer

White-tailed deer are restricted to the southwestern corner of NW Ontario. An FEC interpretation (Figure 10) was prepared to highlight Vegetation Types that are usually capable of producing preferred browse (food) species and winter shelter for the deer in areas to be managed for that purpose (Racey *et al.* 1989a,b).

The limiting factor for white-tailed deer in NW Ontario is usually considered to be winter severity. Tree cover that

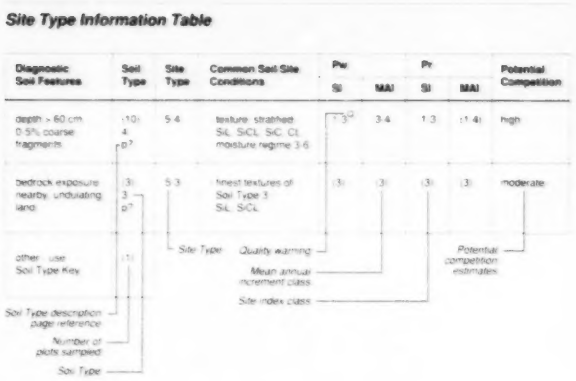

Figure 9. Section of a fact sheet from the Algonquin FEC manual (Merchant *et al.* 1989) highlighting the various parts of the pine productivity "look-up table".

offers some protection from severe cold and deep winter snow is essential. White-tailed deer are generalist herbivores with critical energy requirements, particularly during winter (Racey *et al.* 1989b; however, since most of their energy intake occurs during the snow-free period, good-quality summer forage, especially grasses, deciduous leaves and a variety of herbaceous species, is essential. Other factors include the patterns and juxtapositions of habitat across the landscape, habitat diversity, topography and the general age-class distribution of forest stands in an area.

Similar ordination-based interpretations have been constructed to describe caribou (Morash and Racey 1990) and moose habitats (Racey *et al.* 1989b; Jackson *et al.* 1991) in NW Ontario.

Future Challenge for Forest Site Classification in Ontario

Recently forest management in Canada has entered a phase of ecologically based forestry, with the two-pronged goal of sustaining yield and environmental quality (Kimmins 1991). There is a need, therefore, for a determined shift in our current approach to integrating forest management concerns into operational practice. The various forest users and stakeholders must focus on the achievement of mutual goals, instead of the current approach, under which they attempt to set limits and constraints on each others' jurisdictions and interests.

Although considerable progress has been made over the past 40 years, there are still many new challenges emerging for site classification research in Ontario. Linkages must be strengthened among existing FEC systems and those now under development, so that underlying principles, methodologies, presentation approaches and outputs are standardized, wherever practice. FEC systems are needed for areas of the province not already adequately covered by integrated ecologically-based site classification systems. More research and development is needed to integrate FEC units with timber supply models, wildlife supply models, and, in particular, a variety of specific-purpose, spatially based models, with the use of GIS, remote sensing and other new technologies and tools.

Additional forest management interpretations related to existing FEC systems must be developed so that foresters

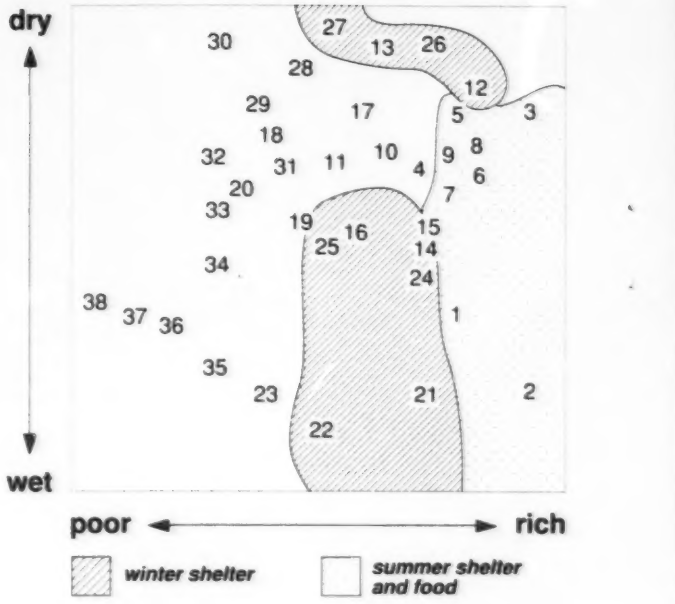

Figure 10. NW Ontario FEC vegetation ordination (as in Figure 4b), overlain with winter and summer shelter and food requirements for white-tailed deer (Racey *et al.* 1989a).

can have better access to up-to-date information classified by site feature. Successful forest management practices must be documented and reported, both by area and by site: it is important for FEC interpretations to be tied to management successes which can be related to specific site features. In this way, FEC will continue to be an important tool for strengthening communication among a variety of policy makers, resource managers and planners, as well as the general public. There are other potential applications for FEC that have not previously been considered. For example, Bailey (1991) outlines a procedure for establishing ecological networks for global-change monitoring which involves the systematic selection of candidate sites on the basis of information acquired from regional site classifications.

As important environmental issues emerge in Ontario, a myriad of new ecosystem-related information needs are being identified. Throughout Ontario, regionally-based ecological data bases need to be collected, perhaps as an adjunct to the provincial FRI program, and organized so that they can be readily accessed for integrated ecosystem-oriented planning. Post-disturbance vegetational classifications should be developed for a range of boreal sites, and perhaps correlated to FEC units. There should be new emphases on understanding processes and functions within boreal forest ecosystems at the landscape level, as well as new research on biodiversity, ecological properties of old-growth forests, and pathways for vegetational succession and long-term ecological change.

Corporate planning and monitoring in a jurisdiction as large as Ontario will need co-ordinated ecological information, and in some instances a common provincial template, on which to develop dynamic inventories and resource management models. The OMNR is currently developing plans for a provincial-scale program of comprehensive, mapping-oriented

ecological land classification (ELC) which incorporates FEC. In this new ELC program, current FEC databases and products will be augmented in a systematic fashion to capture a wider range of ecosystems, with minimal disruption to current FEC users. Efforts will be made to address the broader ecological spectrum by capturing non-forested ecosystems, such as wetlands, within the ELC format. ELC products will be designed to serve a broad range of users and interpretations, and will require the development of new spatial models for area resource management planning. The development of GIS technologies and the linkage to component relational databases and existing forest inventories will undoubtedly comprise a major part of this future work.

Conclusions

Hills' Site Regions are still widely used as a regional-level stratification for a variety of silvicultural purposes, including provincial seed collection zones (Pierpoint 1986). The FEC systems that have been developed subsequently owe much to the initial studies of Hills and his colleagues. Currently available FEC systems in Ontario have found increasing use over the past few years by government and industrial forestry staff as an aid in making day-to-day decisions. The available site classification systems have also been useful for the communication of forest management successes and failures, and for the effective implementation and transfer of new technology and information.

The ecological characteristics of Ontario forest lands must continue to be assessed, and component sites that differ enough to warrant different treatments must be identified. Operational guidelines for foresters can and should be prepared within the framework provided by FEC systems. In a list of recent recommendations, the Forest Research Advisory Council of Canada highlighted the need for a concerted effort to connect research activities with site classification systems (Anonymous 1991). Such an effort may well serve to broaden the use of research results in ways that maximize their application and avoid their use in inappropriate situations. This important activity will continue to be emphasized during the 1990s within the framework of Ontario's FEC and ELC initiatives.

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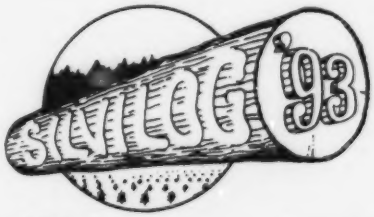

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